

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
22 May 2003 (22.05.2003)

PCT

(10) International Publication Number
WO 03/042146 A1

(51) International Patent Classification⁷: C07C 37/60,
39/04, 39/08

(74) Agents: DE GREGORI, Antonella et al.; Ing. Barzanó
& Zanardo Milano S.p.A., Via Borgonuovo, 10, I-20121
Milan (IT).

(21) International Application Number: PCT/EP02/12169

(22) International Filing Date: 30 October 2002 (30.10.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
MI01A002410 15 November 2001 (15.11.2001) IT

(71) Applicant (*for all designated States except US*):
POLIMERI EUROPA S.p.A. [IT/IT]; Via E. Fermi
4, I-72100 Brindisi (IT).

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU,
AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU,
CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH,
GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC,
LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW,
MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG,
SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ,
VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM,
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW),
Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),
European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE,
ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK,
TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,
GW, ML, MR, NE, SN, TD, TG).

(72) Inventors; and

(75) Inventors/Applicants (*for US only*): **BIANCHI, Daniele**
[IT/IT]; Via Valera 16/C, I-20020 Arese (IT). **D'ALOISIO,**
Rino [IT/IT]; Via Romentino, 25/E, I-28067 Pernate-No-
vara (IT). **TASSINARI, Roberto** [IT/IT]; Via Paletta 8,
I-28100 Novara (IT).

Published:

— with international search report

*For two-letter codes and other abbreviations, refer to the "Guid-
ance Notes on Codes and Abbreviations" appearing at the begin-
ning of each regular issue of the PCT Gazette.*

BEST AVAILABLE COPY

(54) Title: PROCESS FOR THE PREPARATION OF HYDROXYLATED AROMATIC COMPOUNDS

(57) Abstract: A process is described for preparing hydroxylated aromatic compounds by means of the direct oxidation of an aromatic substrate with hydrogen peroxide in a triphasic reaction system, in the presence of a TS-1 zeolitic catalyst.

WO 03/042146 A1

5

PROCESS FOR THE PREPARATION OF HYDROXYLATED AROMATIC COM-
POUNDS

The present invention relates to a process for the
10 preparation of hydroxylated aromatic compounds by means of
the direct oxidation of an aromatic substrate with hydrogen
peroxide.

More specifically, the invention relates to an im-
proved process for the preparation of hydroxylated aromatic
15 compounds in which the oxidation reaction with hydrogen
peroxide is carried out in a triphasic system, in the pres-
ence of a TS-1 zeolitic catalyst.

Hydroxylated aromatic compounds are used as intermedi-
ates for the production of phyto-medicines, dyes, pharma-
20 ceutical compounds, antioxidants, synthetic resins and in-
secticides.

Among hydroxylated aromatic compounds of major inter-
est from a commercial point of view, phenol can be men-
tioned, which is currently industrially produced from cu-
25 mène.

Various processes for the direct oxidation of aromatic substrates, with hydrogen peroxide in the presence of suitable catalytic systems, are known in the art.

These processes are generally carried out in an organic solvent capable of improving the contact between the
5 organic substrate and hydrogen peroxide.

The solvents commonly used are selected from alcohols such as methanol, ethanol or isopropyl alcohol, ketones such as acetone, methylethylketone, or acetic acid or acetonitrile as described in U.S. patents 4,396,783, GB
10 2,116,974.

Improvements in the conversion and selectivities of the above processes can however be obtained by operating in the presence of particular solvents such as, for example,
15 sulfolane (EP A 919531).

A further process improvement can also be achieved through an activation treatment of the catalyst in an aqueous medium with hydrogen peroxide and in the presence of fluorine ions, as described in European patent application
20 EP A 958861.

The processes of the known art are generally carried out in a (solid/liquid) biphasic system.

It has now been found that by operating in a triphasic reaction system consisting of solid catalyst/aqueous
25 phase/organic phase (aromatic compound + solvent) instead

of a biphasic system (solid catalyst/organic phase), it is possible to increase the productivity of oxidation processes of aromatic substrates without jeopardizing the selectivity. Furthermore, by operating in this system, it is possible to significantly reduce the quantity of organic solvent and consequently the dimensions of the recovery section, whose cost greatly influences the overall cost of the process.

An object of the present invention therefore relates to a process for the preparation of hydroxylated aromatic compounds comprising the direct oxidation of an aromatic substrate with hydrogen peroxide, characterized in that the process is carried out in a triphasic reaction system comprising a first liquid phase consisting of the aromatic substrate and an organic solvent, a second liquid phase consisting of water and a solid phase consisting of a catalyst based on titanium silicalite TS-1.

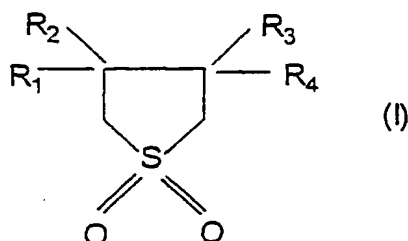
The triphasic reaction system is reached when operating with a controlled quantity of water which is such as to cause the demixing of the liquid phase and prevent the aggregation of the catalyst.

It is convenient to operate with a water concentration ranging from 5 to 60% by weight, preferably using concentrations ranging from 10 to 40%.

The organic solvent can be selected from the solvents

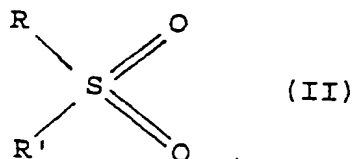
commonly used in oxidation processes described in the known art such as methanol, ethanol, isopropyl alcohol, acetone, methylethylketone, acetic acid or acetonitrile.

The process is preferably carried out in the presence
5 of solvents having formula (I)



10

wherein: R_1 , R_2 , R_3 and R_4 , the same or different, are hydrogen atoms or alkyl groups with from 1 to 4 carbon atoms, or among the compounds having general formula (II)



15

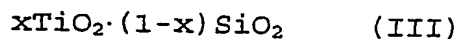
wherein R and R', the same or different, represent an alkyl radical with from 1 to 4 carbon atoms, described in European patent application EP A 919531.

20 Particularly preferred for the purposes of the present invention are compounds having general formula (I) and, among these, sulfolane is preferred.

The solvent is used in quantities ranging from 20 to 80% by weight with respect to the reaction mixture.

25 Quantities ranging from 40 to 60% are preferably used.

The catalysts used in the process of the present invention are selected from those having general formula (III):



5 wherein: x ranges from 0.0001 to 0.04, preferably from 0.02 to 0.03.

The above titanium silicalites can be prepared according to the method described in U.S. patent 4,410,501 in which their structural characteristics are also described.
10 The titanium silicalites can also be subjected to activation treatment as described in patent EP A 958861.

Titanium silicalites in which part of the titanium is substituted by other metals such as boron, aluminum, iron or gallium, can also be used.

15 These substituted titanium silicalites and the methods for their preparation are described in European patent applications 226,257, 226,258 and 266,825.

The catalyst is generally used in quantities ranging from 2 to 60% by weight with respect to the aromatic substrate.
20

Quantities of catalyst ranging from 5 to 40% by weight with respect to the aromatic substrate are preferably used.

The hydrogen peroxide is added to the reaction mixture in quantities ranging from 5 to 50% in moles with respect
25 to the aromatic substrate, preferably from 10 to 30% in

moles.

Solutions of hydrogen peroxide with a concentration ranging from 10 to 60% by weight, preferably from 15 to 60% by weight, are conveniently used. Aromatic substrates which
5 can be used in the process of the present invention can be selected from benzene, toluene, ethylbenzene, chlorobenzene, anisole, phenol and naphthol.

The aromatic substrate is generally used in quantities ranging from 20 to 80% by weight with respect to the reaction mixture.
10

Quantities of aromatic substrate ranging from 30 to 60% by weight with respect to the reaction mixture are preferably used.

The oxidation reaction is carried out at temperatures ranging from 50° to 110°C, preferably from 70° to 100°C.
15

The reaction time necessary for the complete use of the hydrogen peroxide depends on the reaction conditions used.

At the end of the reaction, the reaction products and non-reacted aromatic substrate are recovered by means of
20 the conventional techniques such as fractionated distillation and crystallization.

The process of the present invention can be carried out in reactors of the semi-batch type (with hydrogen peroxide feeding) or of the CSTR type (continuous stirred
25

batch reactor) with continuous feeding of the hydrogen peroxide and benzene/solvent mixture.

When operating in a continuous process, the aqueous phase (in which the catalyst is selectively distributed),
5 is kept inside the reactor removing the organic phase to a quiet non-stirred area in which the demixing takes place. In this way, only one phase is obtained at the outlet, containing: an aromatic compound, a solvent, a hydroxy-aromatic compound and the by-products.

10 When operating under the process conditions of the invention, it is also possible to operate at 100°C obtaining an increase in the catalytic activity (TN Ti) without a loss in selectivity, as would normally happen when operating in a double phase.

15 The following examples, whose sole purpose is to describe the present invention in greater detail, should in no way be interpreted as limiting the scope to the invention itself.

The experimentation was carried out using a jacketed,
20 AISI 316 steel reactor having a capacity of 600 ml, equipped with a mechanical stirrer, feeding lines of the reagents, temperature control and reflux condenser cooled to 0°C.

The solution of H₂O₂ and, in the case of a continuous
25 functioning, the benzene/solvent mixture, were fed by means

of piston pumps.

EXAMPLE 1

Activation of the catalyst

3.0 g (1.43 mmoles of Ti) of TS-1 catalyst (EniChem,
5 Ti = 2.29% by weight) and 0.11 g of NH_4HF_2 (average titer
92.5%) in 35 ml of water, corresponding to a molar ratio
 $\text{F/Ti} = 2.5$, are charged into a 100 ml glass flask, equipped
with a mechanical stirrer, reflux condenser, thermometer
and oil-circulation thermostat. The aqueous suspension of
10 the catalyst, maintained under mechanical stirring, is
heated to 60°C. 1.6 ml of H_2O_2 at 30% by weight, equal to a
molar ratio $\text{H}_2\text{O}_2/\text{Ti} = 11$, are subsequently added, and the
suspension is maintained under stirring at 60°C for 4
hours. After cooling, the solid is separated from the
15 mother liquor (pH 4.3) by filtration on a porous septum,
repeatedly washed with deionized water and finally with
acetone. The catalyst is then dried under vacuum at 40°C
for 8 hours and subjected, at a heating rate of 50°C/h, to
thermal treatment in air at 550°C for 4 hours. Titer of the
20 activated catalyst = 1.49% of Ti. The dissolved titanium
corresponds to 35% by weight.

EXAMPLE 2

Comparative example: biphasic system (operating under the
conditions described in patent EP A 958,861)

25 An AISI 316 reactor (volume = 600 ml) is pressurized

with nitrogen at a pressure of 5 atm. 100 g of benzene (1.28 moles), 200 g of sulfolane and 10 g of catalyst activated as described in Example 1 (equal to 3.1 mmol of Ti), are then charged. The liquid phase of the reaction mixture in this case is homogeneous. The temperature of the reactor is brought to 80°C. 14.5 g (128 mmol of H₂O₂; H₂O₂/benzene = 0.1) of an aqueous solution of H₂O₂ at 30% w/w) are subsequently added over a period of two hours.

After 15 minutes of conditioning at a constant temperature, under stirring, the reaction mixture is cooled to 20°C and the catalyst is separated by filtration on a porous septum.

The solution is analyzed by means of HPLC revealing the formation of the following products:

15 phenol	7.5 g (79.8 mmol)
hydroquinone	traces (0 mmol)
catechol	traces (0 mmol)

The reaction mixture was then evaporated at reduced pressure obtaining 1.2 g of polyphenol pitches (corresponding to 10.9 mmol of C₆H₆O₂ monomer), as boiler residue.

The reaction performances are consequently as follows:

- benzene conversion (C1) = 7.1% (in moles);
- H₂O₂ conversion (C2) = 99% (in moles);
- selectivity to phenol (S1) = 88% (in moles);
- 25 - selectivity with respect to H₂O₂ (S2) = 63% (in

moles);

- hourly turnover (TOF) = 11 (phenol moles/Ti moles per hour)
- phenol concentration in the final reaction mixture = 2.38% (by weight).

Operating under these conditions, during the recovery and purification phase of the reaction products, it is necessary to evaporate 41.0 Kg of solvent (sulfolane and non-reacted benzene) per Kg of phenol.

10 EXAMPLE 3

Comparative example: biphasic system

The same procedure is adopted as described in Example 2, but adding 21.75 (192 mmols of H_2O_2 ; H_2O_2 /benzene = 0.15) of an aqueous solution of H_2O_2 at 30% w/w; in 1 hour at a temperature of 100°C.

The solution is analyzed by means of HPLC revealing the formation of the following products:

phenol	9.64 g (102.6 mmols)
hydroquinone	286 mg (2.6 mmols)
20 catechol	429 mg (3.9 mmols)

The reaction mixture was then evaporated at reduced pressure obtaining 2.46 g of polyphenol pitches (corresponding to 22.4 mmols of $\text{C}_6\text{H}_6\text{O}_2$ monomer), as boiler residue.

25 The reaction performances are consequently as follows:

- benzene conversion (C1) = 10.3% (in moles);
- H₂O₂ conversion (C2) = 99% (in moles);
- selectivity to phenol (S1) = 78% (in moles);
- selectivity with respect to H₂O₂ (S2) = 54% (in moles);
- hourly turnover (TOF) = 33 (phenol moles/Ti moles per hour)
- phenol concentration in the final reaction mixture = 3.00% (by weight).

Operating under these conditions, during the recovery and purification phase of the reaction products, it is necessary to evaporate 32.3 Kg of solvent (sulfolane and non-reacted benzene) per Kg of phenol.

EXAMPLE 4

Triphasic system under semi-batch conditions

An AISI 316 reactor (volume = 600 ml) is pressurized with nitrogen at a pressure of 5 atm. 100 g of benzene (1.28 moles), 180 g of sulfolane 43 g of water and 10 g of catalyst activated as described in Example 1 (equal to 3.1 mmols of Ti), are then charged. The liquid fraction of the reaction mixture in this case is biphasic. The temperature of the reactor is brought to 80°C. 14.5 g (128 mmols of H₂O₂; H₂O₂/benzene = 0.1) of an aqueous solution of H₂O₂ at 30% w/w) are subsequently added over a period of two hours.

The reaction mixture is then cooled to 20°C and the

catalyst is separated by filtration on a porous septum.

The liquid phase is analyzed by means of HPLC revealing the formation of the following products:

	phenol	8.7 g (92.4 mmol)
5	hydroquinone	264 mg (2.4 mmol)
	catechol	385 mg (3.5 mmol)

The reaction mixture was then evaporated at reduced pressure obtaining only traces of polyphenol pitches as boiler residue.

10 The reaction performances are consequently as follows:

- benzene conversion (C1) = 7.7% (in moles);
- H₂O₂ conversion (C2) = 95% (in moles);
- selectivity to phenol (S1) = 94% (in moles);
- selectivity with respect to H₂O₂ (S2) = 76% (in
15 moles);
- hourly turnover (TOF) = 15 (phenol moles/Ti moles per hour)
- phenol concentration in the organic phase = 3.11% (by weight).

20 Operating under these conditions, during the recovery and purification phase of the reaction products, it is necessary to evaporate 31.2 Kg of solvent (sulfolane and non-reacted benzene) per Kg of phenol.

EXAMPLE 5

25 Triphasic system under semi-batch conditions

The same procedure is adopted as in Example 4, but adding 21.75 (192 mmol of H_2O_2 ; $\text{H}_2\text{O}_2/\text{benzene} = 0.15$) of an aqueous solution of H_2O_2 at 30% w/w, in 2 hours at a temperature of 80°C.

5 The solution is analyzed by means of HPLC revealing the formation of the following products:

phenol	12.7 g (135.0 mmol)
hydroquinone	660 mg (6.0 mmol)
catechol	990 mg (9.0 mmol)

10 The reaction mixture was then evaporated at reduced pressure obtaining only traces of polyphenol pitches as boiler residue.

The reaction performances are consequently as follows:

- benzene conversion (C1) = 11.7% (in moles);
- 15 - H_2O_2 conversion (C2) = 95% (in moles);
- selectivity to phenol (S1) = 90% (in moles);
- selectivity with respect to H_2O_2 (S2) = 74% (in moles);
- hourly turnover (TOF) = 22 (phenol moles/Ti moles per
20 hour)
- phenol concentration in the final reaction mixture = 4.53% (by weight).

Operating under these conditions, during the recovery and purification phase of the reaction products, it is necessary to evaporate 21.1 Kg of solvent (sulfolane and non-
25

reacted benzene) per Kg of phenol.

EXAMPLE 6

Triphasic system under semi-batch conditions

The same procedure is adopted as in Example 4, but
5 adding 21.75 (192 mmol of H_2O_2 ; $\text{H}_2\text{O}_2/\text{benzene} = 0.15$) of an aqueous solution of H_2O_2 at 30% w/w, in 1 hour at a temperature of 100°C.

The solution is analyzed by means of HPLC revealing the formation of the following products:

10	phenol	13.3 g (141.1 mmol)
	hydroquinone	693 mg (6.3 mmol)
	catechol	1034 mg (9.4 mmol)

The reaction mixture was then evaporated at reduced pressure obtaining only traces of polyphenol pitches as
15 boiler residue.

The reaction performances are consequently as follows:

- benzene conversion (C1) = 12.2% (in moles);
- H_2O_2 conversion (C2) = 98% (in moles);
- selectivity to phenol (S1) = 90% (in moles);
- 20 - selectivity with respect to H_2O_2 (S2) = 75% (in moles);
- hourly turnover (TOF) = 46 (phenol moles/Ti moles per hour)
- phenol concentration in the final reaction mixture =
25 4.75% (by weight).

Operating under these conditions, during the recovery and purification phase of the reaction products, it is necessary to evaporate 20.1 Kg of solvent (sulfolane and non-reacted benzene) per Kg of phenol.

5 A comparison between the results obtained in the biphasic and triphasic system, operating under semi-batch conditions, is provided in Table 1.

10

15

20

Table 1

Example nr.	Benzene % w/w (a)	Sulfolane % w/w (a)	H ₂ O % w/w (a)	H ₂ O ₂ (b)	T °C	Conv. % benzene (C1)	Selec. % benzene (S1)	Selec. % H ₂ O ₂ (S2)	TOF (c)	Conc. % phenol (d)	Kg solv. Kg _{phenol} (e)
2	33	67	0	10	80	7.1	88	63	11	2.38	41.0
3	33	67	0	15	100	10.3	78	54	33	3.00	32.3
4	31	56	13	10	80	7.7	94	76	15	3.11	31.2
5	31	56	13	15	80	11.7	90	74	22	4.53	21.1
6	31	56	13	15	100	12.2	90	75	46	4.75	20.1

(a) weight percentage with respect to the reaction mixture

(b) H₂O₂ moles/benzene moles

(c) hourly turnover of titanium (phenol moles/titanium moles per hour)

(d) wt % concentration of phenol in the final reaction mixture (in the triphasic system only the organic phase was considered)

(e) Kg of solvent to be evaporated in the recovery phase per 1 Kg of phenol produced.

EXAMPLE 7Triphasic system under CSTR conditions (process in continuous)

An AISI 316 reactor (volume = 600 ml) was equipped
5 with a column (material: AISI 316, internal diameter: 1
cm), fixed at the head, and immersed in the reaction mixture. A non-stirred zone is created inside the column, in
which it is possible to selectively remove the organic
phase (light phase).

10 The reactor is pressurized with nitrogen at a pressure
of 5 atm. 100 g of benzene (1.28 moles), 150 g of sulfolane
150 g of water and 50 g of catalyst activated as described
in Example 1 (equal to 15.5 mmoles of Ti), are then
charged. The liquid fraction of the reaction mixture in
15 this case is biphasic. The temperature of the reactor is
brought to 100°C.

A mixture of benzene (38.3% by weight), sulfolane
(57.5% by weight and H₂O₂ (solution at 60% w/w) is then
fed in continuous (flow: 500 g/hour).

20 766 g of benzene (9.82 moles) and 84 g of H₂O₂ (60%
w/w; 1.48 moles), corresponding to a H₂O₂/benzene ratio =
0.15, are then fed over a period of 4 hours.

The level inside the reactor is kept constant by re-
moving the organic phase which is separated in the quiet
25 zone inside the tube immersed in the reaction medium.

The organic phase is subsequently analyzed by means of HPLC revealing the formation of the following products:

	phenol	88.5 g (942 mmols)
	hydroquinone	6.16 g (56 mmols)
5	catechol	9.24 mg (84 mmols)

The reaction mixture was then evaporated at reduced pressure obtaining only traces of polyphenol pitches as boiler residue.

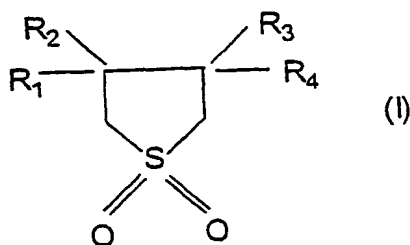
The reaction performances are consequently as follows:

- 10 - benzene conversion (C1) = 11.0% (in moles);
- H₂O₂ conversion (C2) = 95% (in moles);
- selectivity to phenol (S1) = 87% (in moles);
- selectivity with respect to H₂O₂ (S2) = 67% (in moles);
- 15 - hourly turnover (TOF) = 30 (phenol moles/Ti moles per hour)
- phenol concentration in the organic phase = 4.43% (by weight).

Operating under these conditions, during the recovery
20 and purification phase of the reaction products, it is necessary to evaporate 21.6 Kg of solvent (sulfolane and non-reacted benzene) per Kg of phenol.

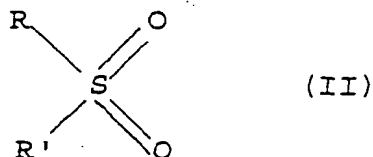
CLAIMS

1. A process for the preparation of hydroxylated aromatic compounds comprising the direct oxidation of an aromatic substrate with hydrogen peroxide, characterized in that the process is carried out in a triphasic reaction system comprising a first liquid phase consisting of the aromatic substrate and an organic solvent, a second liquid phase consisting of water and a solid phase consisting of a catalyst based on titanium silicate TS-1.
2. The process according to claim 1, wherein the quantity of water in the reaction system ranges from 5 to 60% by weight.
3. The process according to claim 2, wherein the quantity of water ranges from 10 to 40%
4. The process according to claim 1, wherein the organic solvent is selected from solvents having formula (I)



wherein: R₁, R₂, R₃ and R₄, the same or different, are hydrogen atoms or alkyl groups with from 1 to 4 carbon atoms, or among the compounds having general formula

(II)



5 wherein R and R', the same or different, represent an alkyl radical with from 1 to 4 carbon atoms.

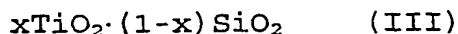
5. The process according to claim 4, wherein the organic solvent is selected from the compounds having general formula (I).

10 6. The process according to claim 5, wherein the organic solvent is sulfolane.

7. The process according to claim 1, wherein the organic solvent is used in quantities ranging from 20 to 80% by weight with respect to the reaction mixture.

15 8. The process according to claim 7, wherein the organic solvent is used in quantities ranging from 40 to 60%.

9. The process according to claim 1, wherein the catalyst is selected from those having general formula (III):



20 wherein: x ranges from 0.0001 to 0.04, preferably from 0.02 to 0.03.

10. The process according to claim 9, wherein the catalyst is used in quantities ranging from 2 to 60% with respect to the aromatic substrate.

25 11. The process according to claim 10, wherein the cata-

lyst is used in quantities ranging from 5 to 40% with respect to the aromatic substrate.

12. The process according to claim 9, wherein the catalyst is subjected to activation treatment.

5 13. The process according to claim 1, wherein the hydrogen peroxide is added to the reaction mixture in quantities ranging from 5 to 50% in moles with respect to the aromatic substrate.

10 14. The process according to claim 13, wherein the hydrogen peroxide is added to the reaction mixture in quantities ranging from 10 to 30% in moles with respect to the aromatic substrate.

15 15. The process according to claim 1, wherein the hydrogen peroxide is used in a solution at a concentration ranging from 10 to 60%.

16. The process according to claim 15, wherein the hydrogen peroxide is used in a solution at a concentration ranging from 15 to 60% by weight.

20 17. The process according to claim 1, wherein the aromatic substrate is selected from benzene, toluene, ethylbenzene, chlorobenzene, anisole, phenol and naphthol.

18. The process according to claim 17, wherein the aromatic substrate is benzene.

25 19. The process according to claim 1, wherein the aromatic substrate is used in quantities ranging from 20 to 80%

by weight with respect to the reaction mixture.

20. The process according to claim 19, wherein the aromatic substrate is used in quantities ranging from 30 to 60% by weight with respect to the reaction mixture.

5 21. The process according to claim 1, wherein the oxidation reaction is carried out at temperatures ranging from 50° to 110°C.

22. The process according to claim 21, wherein the oxidation reaction is carried out at temperatures ranging
10 from 70° to 100°C.

23. The process according to claim 1, wherein the oxidation reaction is carried out in reactors of the semi-batch type, with feeding of hydrogen peroxide, or of the CSTR type (continuous stirred batch reactor) with
15 continuous feeding of hydrogen peroxide and of the aromatic substrate/solvent mixture.

INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 02/12169

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 C07C37/60 C07C39/04 C07C39/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C07C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 919 531 A (ENICHEM SPA) 2 June 1999 (1999-06-02) the whole document	1-23
X	EP 0 958 861 A (ENI SPA ; ENICHEM SPA (IT)) 24 November 1999 (1999-11-24) *abstract; pages 2-4; examples 17-47 and the claims	1-23
X	US 5 811 599 A (ALIVE KESHA VARAJA ET AL) 22 September 1998 (1998-09-22) *abstract; columns 1-3; column 5, lines 29-51; examples 2-12 and the claims*	1-23
X	EP 0 791 558 A (ENICHEM SPA) 27 August 1997 (1997-08-27) *abstract; examples 24-28 and the claims*	1-3, 7-13, 17-23
	--- -/-	

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

* Special categories of cited documents :

A document defining the general state of the art which is not considered to be of particular relevance

E earlier document but published on or after the international filing date

L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

O document referring to an oral disclosure, use, exhibition or other means

P document published prior to the international filing date but later than the priority date claimed

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

Z document member of the same patent family

Date of the actual completion of the international search

24 January 2003

Date of mailing of the international search report

05/02/2003

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Lorenzo Varela, M.J.

INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 02/12169

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 894 783 A (ENICHEM SPA) 3 February 1999 (1999-02-03) *abstract; claims 1 and 24-28* -----	1-23
BEST AVAILABLE COPY		

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP 02/12169

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 0919531	A	02-06-1999	IT MI972629 A1	27-05-1999
			EP 0919531 A1	02-06-1999
			JP 11240847 A	07-09-1999
			RU 2185368 C2	20-07-2002
			TW 466230 B	01-12-2001
			US 6133487 A	17-10-2000
EP 0958861	A	24-11-1999	IT MI981087 A1	19-11-1999
			IT MI982712 A1	19-06-2000
			DE 69901654 D1	11-07-2002
			EP 0958861 A1	24-11-1999
			JP 2000202305 A	25-07-2000
			RU 2159675 C1	27-11-2000
			US 6288004 B1	11-09-2001
US 5811599	A	22-09-1998	NONE	
EP 0791558	A	27-08-1997	IT MI960330 A1	22-08-1997
			IT MI961836 A1	06-03-1998
			AT 210077 T	15-12-2001
			CZ 9700543 A3	17-09-1997
			DE 69708723 D1	17-01-2002
			DE 69708723 T2	14-08-2002
			DK 791558 T3	18-03-2002
			EP 0791558 A1	27-08-1997
			ES 2167626 T3	16-05-2002
			JP 10001309 A	06-01-1998
			PL 318605 A1	01-09-1997
			PT 791558 T	31-05-2002
			SI 791558 T1	30-04-2002
			SK 23597 A3	04-03-1998
			TW 403722 B	01-09-2000
			US 5965476 A	12-10-1999
EP 0894783	A	03-02-1999	IT MI971806 A1	29-01-1999
			EP 0894783 A1	03-02-1999